arrangements are possible. It is recommended that square-shaped trenches be avoided, because the high peak fields that appear at the trench corners can result in the premature breakdown of the device.

Mesa region and trench widths are design parameters that have a significant impact on rectifier performance. Both widths affect the breakdown voltage of the rectifier (with a narrower mesa region or a wider trench increasing breakdown voltage), and the Schottky/P^+ ratio affects V_{FD} and the reverse recovery charge Q_n.

A simulated plot of V_{FD} versus current density is shown in FIG. **11** for a rectifier having the structure shown in FIG. **3**, with a mesa region width of about 4 μm and a trench width of about 2 μm. This results in a structure in which the Schottky region and the trenches occupy about 67% and 33% of the device area, respectively. As seen in FIG. **11**, the current density in the P^+ regions (short dashes) is much lower than that found in the Schottky region (long dashes). The solid line shows the total current density through the device.

A plot of current flow versus time for a rectifier per the present invention (trace "**170**") and a commercial "fast recovery" P-i-N rectifier (trace "**172**") is shown in FIG. **12**, showing what happens to current flow when the rectifiers are turned off while carrying a forward current of 50 A. Though the quantity of stored charge Q_n is about the same for the two devices (Q_n(invention)≅5.5 μC; Q_n(P-i-N)≅5.2 μC), the new rectifier has a much smaller peak reverse recovery current I_{RP} (~27 A vs. ~74 A). In addition, the new rectifier provides a soft recovery characteristic, as opposed to the P-i-N rectifier's snappy recovery characteristic. The lower I_{RP} and soft recovery help to reduce the stress on associated components subjected to the current through the rectifier.

One application of a rectifier per the present invention is illustrated in FIG. **13**. As described in J. Baliga (ibid.) at p. 575–577, a PWM motor control circuit **178** provides variable frequency AC power to a 3-phase AC motor **180** using six switching transistors and six flyback diodes. Each switch is made from two transistors connected in a totem-pole configuration: one switch (typical of all the switches), is made from a pair of transistors **182**, **184** connected in series between a high voltage DC bus and ground, with a flyback diode 150 per the present invention connected across each transistor. The switching transistors are driven by a gate drive circuit **186**, which regulates power to the motor by adjusting the time duration for the on and off states of each switch. In a motor control circuit application, insulated-gate bipolar transistors (IGBTs) are typically used for the switching transistors, due to their high reverse blocking voltage and excellent switching characteristics, and because they do not require a snubber circuit. Rectifiers 150 per the present invention are well-suited for use in the motor control circuit, due to their superior forward voltage drop, reverse recovery, and reverse blocking characteristics. These factors combine to improve the efficiency of the motor control circuit, while reducing the stress on the switching transistors.

The high power rectifier is fabricated using conventional means well-known to those in the art of semiconductor fabrication. Though the device's trench structures require processing steps that are not necessary when fabricating other rectifier types, such as a P-i-N or MPS rectifier, the additional fabrication complexity is offset by the greatly improved performance of the device when used in high power applications.

While particular embodiments of the invention have been shown and described, numerous variations and alternate

embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.

I claim:

1. A rectifier device, comprising:

an N^+ layer,

a first layer of metal on said N^+ layer providing a first connection point for said device,

an N^- drift layer on said N^+ layer opposite said first layer of metal,

a first pair of trenches recessed vertically into said drift layer opposite said N^+ layer, said trenches separated by a mesa region,

a layer of oxide lining the sides of each of said trenches to form oxide side-walls in each of said trenches,

a respective shallow P^+ region in said N^- drift layer at the bottom of each of said trenches which extends around the corners at the bottoms of said sidewalls to protect said corners from high peak electric fields when said device is reverse-biased, the separation between said shallow P^+ regions being less than the ambipolar diffusion length of the device,

a conductive material in each of said trenches for conducting current from the top of each trench to its respective shallow P^+ region, said conductive material comprising polysilicon which has been heavily-doped with acceptors, and

a second layer of metal contacting said mesa region, said conductive material, and said oxide side-walls, said second layer of metal forming a Schottky contact at its interface with said mesa region, said second layer of metal providing a second connection point for said device,

said N^+ layer, said N^- drift layer, said first and second layers of metal, said first pair of trenches, said layer of oxide, said respective shallow P^+ regions, and said conductive material arranged such that a voltage applied across said connection points which forward-biases the device produces conductivity modulation in said drift region allowing current to flow from said second to said first connection point via said Schottky contact and said shallow P^+ regions, and a voltage applied across said connection points which reverse-biases the device produces depletion regions alongside said side-walls and around said shallow P^+ regions which provide a potential barrier that shields said Schottky contact from a high electrical field and thereby reduces reverse leakage current.

2. The rectifier device of claim **1**, wherein the doping level of said shallow P^+ regions is at least 1×10^{18} carriers per cm^3.

3. The rectifier device of claim **1**, wherein said N^+ layer is a bulk substrate material and said N^- drift layer is an epitaxial layer grown on said N^+ layer.

4. The rectifier device of claim **1**, wherein said N^- drift layer is a bulk substrate material and said N^+ layer is implanted into the backside of said N^- layer.

5. The rectifier device of claim **1**, wherein the depth of each of said trenches is between about 1 μm and 3 μm.

6. The rectifier device of claim **1**, wherein said shallow P^+ regions are about 0.5 μm thick to limit lateral diffusion.

7. The rectifier device of claim **1**, wherein the width of each of said trenches is about equal, and the width of said mesa region is about twice as wide as that of a trench.

8. The rectifier device of claim **7**, wherein the width of each of said trenches is about 2 μm and the width of said mesa region is about 4 μm.